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Quality Assessment Criteria: Psychometric properties of measurement tools for Cancer Related Fatigue

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Abstract

Background: Fatigue is a common and distressing cancer symptom that negatively affects the quality of life. Many scales have been developed to assess cancer-related fatigue. The properties of the scales vary in terms of dimensionality, reliability, validity, length, and method of administration. Insufficient of psychometric properties may affect the accuracy of scales findings, that may lead result obtained questionable. The main objective of this review was to conduct a quality assessment of the psychometric properties of cancer-related fatigue scales to identify appropriate scales that could be used in research and clinical practice.

Method: A systematic search was carried out to identify validated scales that measure cancer-related fatigue. Five databases were searched: CINAHL, MEDLINE, EMBASE, PsycINFO, Cochrane Library. This review was conducted following the PRISMA and Terwee et al.'s quality assessment guidelines to evaluate the psychometric properties of the studies.

Result: Seventy-one different studies published between 1970 and 2018 met the inclusion criteria. Twenty-five scales were identified. Of these, eighteen were multidimensional and seven were uni-dimensional, containing between 4 and 72 items. Reliability and/or validity information was missing for many scales. Four scales met the quality assessment criteria and were reported as the most appropriate for measuring fatigue in cancer patients.

Conclusion: Further psychometric testing is required for other scales. Developing a universally-defined tool kit for the assessment of cancer-related fatigue may help clarify the concept of fatigue and promote a systematic approach to fatigue measurement.

Key words: Review, Cancer-Related Fatigue, Scales, Validity, Reliability.

Introduction

A cancer diagnosis is a major life stressor that affects an individual's physiological and psychological state. Patients may experience symptoms related to their cancer and/or cancer treatment with fatigue being a common and distressing symptom. Estimated prevalence rates range from 50% and 90% [1]. The variation in prevalence among similar cancer patient populations may be partially dependent upon how Cancer-Related Fatigue (CRF) is measured. Many cancer patients described fatigue highly distressing symptom affecting their quality of life [2,3]. Fatigue occurs during cancer diagnosis, treatment and throughout the survival trajectory [4] including long-term disease-free survivors [5], and advanced cancer patients [1]. CRF typically increases during radiation [6], chemotherapy [7] , and biological therapy [8].

Despite the prevalence of CRF, there is no universally agreed upon definition of CRF or gold standard questionnaire to measure this troubling symptom [9]. One of the most commonly cited definitions, proposed by the National Comprehensive Cancer Network (NCCN), states that fatigue is 'a distressing persistent subjective sense of physical, emotional, and/or cognitive tiredness or exhaustion related to cancer or cancer treatment that is not proportional to recent activity that interferes with usual functioning' [10]. The European Association for Palliative Care (EAPC) defined CRF as a 'subjective feeling of tiredness, weakness or lack of energy' [11]. Both definitions described CRF as subjective, indicating that the assessment of fatigue should be solicited directly from the individual. One difference between the EAPC and NCCN definitions is the impact of CRF on functioning, with the latter being more comprehensive to include the consequences of fatigue on function. The conceptual definition of CRF should guide the operationalization of outcome measures used in research studies. Consequently, the different CRF definitions employed within research studies may help explain the variety of scales used to measure fatigue.

Researchers strive to use CRF scales with acceptable reliability and validity. Insufficient reporting or testing of psychometric properties may affect the accuracy of findings, leading to questionable study results [12–14]. The use of valid and reliable scales to measure CRF may lead to

improvement in patient care and development of fatigue guidelines. Four previous systematic reviews have been published which explore the reliability and validity of CRF measuring scales [15–18]. Whilst such reviews were helpful, they did not employ any structured quality assessment criteria to determine the psychometric properties of the scales being reviewed. Terwee et al. [19] provided researchers with quality assessment criteria to evaluate studies that have reported the psychometric properties of questionnaires. Hence, the purpose of this review is to assess the psychometric properties of CRF scales using the Terwee et al.'s quality assessment criteria.

Methods

Search Strategy

A systematic literature search was conducted using the following electronic databases: CINAHL, MEDLINE, EMBASE, PsycINFO, Cochrane Library, for the period from 1946 to December 2018. The search strategy used in each database was as follows: (MH "Patient Assessment+") OR (MH "Clinical Assessment Tools+") OR (MH "Functional Assessment+") OR (MH "Outcome Assessment"); (MH "Outcome Assessment") OR (MH "Measurement Issues and Assessments+"); (MH "Inventories"); (MH "Scales"); (MH "Cancer Fatigue") OR (MH "Fatigue Syndrome, Chronic"); (fatigue adj (scale or inventory or instrument or measurement or assessment)).mp.; (MH "Process Assessment (Health Care) +"); (MH "Clinical Assessment Tools+"); (MH "Measurement Issues and Assessments+") OR (MH "Psychometrics"); (MH "Fatigue+"); (MH "Hematologic Neoplasms+"); (MH "Palliative Care"); Neoplasm*; (MH "Cancer Fatigue") OR (MH "Neoplasms+"). Footnote chasing was used to identify any further studies [20].

Selection Criteria

Studies published in English with a stated study purpose to evaluate the psychometric properties of a CRF instrument were eligible for inclusion. People with cancer were the population of interest. Studies were included in the review if study participants met the following inclusion criteria: 1) aged 18 or more; 2) diagnosed with any type of cancer; 3) any stage of cancer; 4) in the case of mixed patient populations, studies were included if more than half of the participants were

diagnosed with cancer. Exclusion criteria were protocol papers and conference abstracts; single-item scales such as visual analogue scales (VAS) and fatigue subscales that were part of quality of life scales.

Assessment of measurement properties of CRF Scales:

Upon retrieval of applicable studies, CRF scales were evaluated to determine dimensionality, (unidimensional that produces one overall fatigue score versus multidimensional that produces subscales score with or without an overall fatigue score), number of items, and method of administration. The psychometric properties of CRF scales of studies included in the review were assessed using Terwee et al.'s [19] quality assessment criteria (Supplementary Table S1). These criteria specifically address eight measurement properties: content validity, internal consistency, criterion validity, construct validity, reproducibility, responsiveness, floor and ceiling effects, and interpretability. Using the descriptors provided by Terwee et al. [19], the eight criteria were applied to each CRF scales within the review and rated as positive (+); indeterminate (?); negative (-); or '0', no information available.

For ease of interpretation, this review is reported in two sections. Section One addresses Terwee et al.'s [19] quality assessment criteria to evaluate each study's report of the CRF scales. Section Two reviewed the scales' characteristics, such as the number of items, dimensions of fatigue, scoring system, administration time, the reporting period for the fatigue assessed, and the quality assessment of the scales. Unidimensional and multidimensional scales are presented separately.

Findings

The search strategy identified 2546 studies, which were screened by abstract and title. Based on the inclusion/exclusion criteria, 71 studies employing 25 different scales were included in the review (Figure 1). There were 7 unidimensional and 18 multidimensional scales; the former produced an overall fatigue score, whereas the multidimensional scales produced subscale scores and an overall CRF score.

The review evaluated 71 studies with five studies reporting more than one scale: four studies evaluated two scales [21–24] and one study evaluated three scales [25]. Each scale in each study was evaluated separately. To account for studies that evaluated multiple CRF scales, the denominator for reporting percentages was 77 studies rather than 71 (66 studies reporting the psychometric properties of one CRF scales, 4 studies reporting two scales, and one study reporting three scales).

Seventy-one psychometric studies involving 17,794 mixed cancer patients were included in this review (See table 1 for a general characteristic of the studies). The sample size ranged from 120 to 800. Study participants were diagnosed with a variety of cancers. The vast majority (n = 60 studies) included those with mixed cancer diagnoses. The remaining studies included women with breast cancer, Hodgkin's lymphoma, prostate, head and neck, and lung cancers. Nineteen different definitions of CRF were identified across the studies however only 32 studies (41.5%) included a definition of CRF. The remaining studies stated that there was no universal definition of CRF. A summary of all definitions used in the studies is presented in Supplementary Table S 2.

Section One: Overall Reporting of Quality Assessment Criteria of CRF Scales

Psychometric properties were assessed for each CRF instrument based on the Terwee et al. [19], checklist (see Table 2 for a summary of the evaluation). Seventy studies (91%) received a positive rating in terms of *content validity*; six (7.8 %) were indeterminate. Only one study [26] provided no information about content validity. *Internal consistency* was reported in 71 studies (92%); 68 received a positive rating (88%) and three had an indeterminate rating (4%) [27–29]. Sixty-two studies received a positive score (80.5%) for *construct validity*, while eight received an indeterminate score (10%) [30–37]. However, six studies provided no information on internal consistency [26,38–42] and one study received a negative rating in terms of construct validity [38] .

Studies evaluated other criterion less frequently. Only 23 studies (29.8%) provided information about *criterion validity*. Of these, 16 studies demonstrated positive (21%) criterion validity [21,27,33,38,42–52] and just seven (9%) received an indeterminate rating [37,53–58]. The remaining 54 (70%) studies did not provide information related to criterion validity. *Agreement* was

only assessed in two studies (2.5%) [26,59], which indicated a positive score for the instrument to detect minimally important changes in CRF. *Reliability* data was reported as being acceptable (i.e., at least 0.07) in 26 (34%) studies. Four studies produced an indeterminate rating (5%), and 47 (61%) studies did not provide any information. *Responsiveness* was evaluated in five studies (6.5%). One (1.3%) study received a positive rating for responsiveness [29], while four studies (5.2%) were rated as indeterminate [22,60,61]. *Floor and ceiling effects* were reported in five studies (6.5%); four receiving positive ratings (5.2%) [23],[23],[62,63] and one (1.3%) an indeterminate rating [32]. Three studies (3.9%) reported *interpretation.* Two (2.6%) received an indeterminate rating [32,64] and one (1.3%) a positive rating [65].

Section Two: Scale Characteristics

The review found seven different unidimensional scales to assess CRF (Supplementary Table S3).

Unidimensional Scales: Twenty-six studies examined the psychometric properties of unidimensional scales: (a) ten explored the Brief Fatigue Inventory (BFI) scale; (b) eight used the Functional Assessment of Chronic Therapy-Fatigue subscale (FACT-F); (c) three studies assessed the Fatigue Severity Scale (FSS) scales; (d) two studies evaluated the Modified Brief Fatigue Inventory (MBFI); and (e) one study measured Four-Items Fatigue Scale (FIFS), Fatigue Assessment Scale (FAS) and Fatigue Items Bank (FIB).

The *BFI* is a measure of fatigue severity for cancer populations [53]. It consists of 9 items using a 11-point numerical rating scale. The original version was published in English. The reliability and validity were established in oncology outpatients, inpatients and healthy populations. The internal consistency (0.96) supports the reliability of the tool [53]. The BFI is quick and easy for participants to complete. This inventory has been translated into a range of languages, including Italian [43], Greek [33], German [44], Taiwan-Chinese [64], Chinese [66], Japanese [45], Korean [37], Indonesian [67] and Filipino [39]. The internal consistency in all translated versions of the BFI was high (between 0.96 to 0.91) and all versions were validated for use in mixed cancer populations. The method of translation from the original version of BFI to other languages was done according to the forward-

backward procedures. In people with cancer, the BFI meets the quality assessment criteria for content, criterion, and construct validity along with internal consistency and interpretation. Further work is needed with regard to agreement, responsiveness and floor and ceiling effects.

The scoring system of the BFI was modified (MBFI) from the original 0-10 point numeric scale to a 1-7 point scale [68]. The same 9 items were retained and validated in patients with head and neck cancer [19]. Two validation studies of the MBFI, showed good internal consistency of the subscales (coefficient alpha 0.93-0.86)[21,68]. In people with cancer, the MBFI meets the quality assessment criteria for content, criterion, and construct validity along with reliability and internal consistency. However, agreement, responsiveness, floor and ceiling effects and interpretation has not been reported.

The 9 items of BFI were reduced to 4 to develop the FIFS [38]. It was tested in patients with different types of cancer. The FIFS did not predict fatigue over time and the reliability of the scale needs to be confirmed in further studies. In people with cancer, the FIFS meets the quality assessment criteria for content and criterion validity. Reliability, internal consistency agreement, responsiveness, floor and ceiling effects and interpretation have yet to be reported.

The *FACT-F* is a 13-item questionnaire using a 5-point Likert scale to assess fatigue [46]. It has been validated for use with a variety of cancer diagnoses and treatments [46]. The original FACT-F showed strong internal consistency (*coefficient alpha* 0.93-0.95) and good stability (*test-retest, r* =0.87) [46]. The FACT-F has been translated in to 57 languages using iterative forward-backward translation methodology [69]. Eden and Kunkel [21] validated the FACT-F with patients with head and neck cancer and reported good internal consistency (Cronbach's alpha 0.87) and test-retest reliability (r=0.95).Other psychometric studies using the instrument translated it into Spanish [61], French and Dutch [70], Japanese [40], Persian [71], and Portuguese [26,72]. Internal consistency of the translated scales ranged from between 0.79 to 0.94. In people with cancer, the *FACT-F* meets the quality assessment criteria for content, criterion, and construct validity along with agreement,

reliability and internal consistency. Further work, however, is needed on responsiveness, floor and ceiling effects, and interpretation.

The *FAS* includes 10-items and uses a 5-point Likert scale to assess physical and mental fatigue. Even though the FAS assesses two dimensions of fatigue, it is categorized as unidimensional as only the overall fatigue score should be used [73,74]. De Vries et al. [75] assessed the psychometric properties in a working population of 560 Dutch breast cancer patients; the results showed good internal consistency (Cronbach's alpha 0.89) and test-retest reliability (r=0.88). The FAS meets the quality assessment criteria for content and construct validity along with internal consistency and reliability. Further work is needed on criterion validity, agreement, responsiveness, floor and ceiling effects and interpretation.

The *FSS* includes 9 items and uses a 7-point Likert scale. The FSS was originally validated in multiple sclerosis and systemic lupus erythematosus populations [76]. The psychometric properties were assessed in advanced cancer patients [54] and mixed cancer patients [28]. The coefficient alpha of the two studies ranged from 0.94 to 0.96. Based on the review findings, the FSS meets the quality assessment criteria for content, criterion, and construct validity along with reliability, internal consistency and interpretation. Agreement, responsiveness and floor and ceiling effects have not been reported.

The *FIB* is a 72-item, 5-point Likert scale which was developed to measure CRF in a computerized adaptive testing format [63]. The scale was validated in 301 mixed cancer patients. The FIB shows good psychometric properties using Rasch analysis. The internal consistency was 0.99 and item total correlation was between 0.51 and 0.85. The factor analysis conformed that 72 items were unidimensional. The authors provided a 6-item short form FIB for use in a clinical setting. In people with cancer, the FIB-72 items met the quality assessment criteria for content and construct validity, floor and ceiling effects along with internal consistency. Further work is needed on criterion validity, agreement, reliability, interpretation and responsiveness.

Multidimensional Scales: The review found 50 studies that investigated the properties of 18 multidimensional scales of fatigue. All 18 multidimensional scales provided an overall fatigue score, as well as subscale scores to represent specific domains of fatigue (Supplementary Table S 4 for more details).

The *Multidimensional Fatigue Inventory (MFI)* is a 20-item, 5-point Likert scale designed to measure general fatigue, physical fatigue, mental fatigue, reduced motivation and reduced activity [77]. The scale was originally validated in Dutch cancer patients, non-cancer chronic fatigue syndrome patients, army recruits and medical students [77]. Smets et al. [78] validated the MFI-20 in a Dutch and Scottish patients with cancer and reported good internal consistency (coefficient alpha 0.79 to 0.93). The MFI-20 has been translated into several languages; French [56], Chinese [57], Brazilian Portuguese [79], Polish [55], Hindi [80], and Swedish [81], utilising the back-translation process. Overall, internal consistency was acceptable in all translated versions of the MFI (between 0.80 to 0.90). In people with cancer, the MFI-20 meets the quality assessment criteria for content, criterion, and construct validity along with internal consistency and interpretation. Further work is needed on test-retested reliability, agreement, responsiveness and floor and ceiling effects.

The *Multidimensional Fatigue Symptom Inventory-Short Form (MFSI-SF)* is a 30-item, 5-point Likert scale that was designed specifically for use with breast cancer patients [82]. There are 5 subscales; physical, emotional, mental, vigour and general fatigue. Initial psychometric testing occurred in 224 breast cancer patients, who were undergoing chemotherapy and radiotherapy, and the scale demonstrated very good validity and reliability [82]. Additional psychometric studies were conducted in English [83], Chinese[84] and Singapore Chinese [60] and the internal consistency of the subscales ranged from 0.74 to 0.96. In people with cancer, the MFSI-SF met the quality assessment criteria for content and construct validity along with internal consistency, reliability and responsiveness. Criterion validity, agreement, floor and ceiling effects and interpretation were not reported.

Schwartz [85] published the first version of the *Schwartz Cancer Fatigue Scale (SCFS),* which has 28-items using a 5-point Likert scale. The *SCFS* assess four fatigue dimensions; physical, cognitive, temporal and emotional and was specifically designed to measure CRF. The coefficient alpha for total scale score was 0.96, and subscales ranged from 0.82 to 0.93. A revised version, the SCFS-6 contains only 6-items, measuring the physical and perceptual dimensions of CRF and has shown good internal consistency (coefficient alpha 0.81 to 0.88) [86] and 0.85 [29]. The SCFS-6 was translated into Chinese and had good internal consistency (coefficient alpha 0.88 to 0.89) [23,25] using backward transitional methods. In people with cancer, the *SCFS-6* met the quality assessment criteria for content and construct validity along with reliability, internal consistency, floor and ceiling effects and responsiveness. Further work is needed on criterion validity, agreement, and interpretation.

The Fatigue Symptom Inventory (FSI) consists of 13 items that assess the intensity, duration, daily pattern and interference of fatigue [87]. The FSI was originally developed using a sample of patients with breast cancer, both during and after treatment. The internal consistency of the subscales had a coefficient alpha above 0.90 in all groups. Hann et al. [88] tested FSI in a mixed cancer population and found an overall coefficient alpha of 0.94. The FSI was translated into Chinese and had a Cronbach's alpha score of between 0.70 to 0.90 [23,25]. In people with cancer, the FSI met the quality assessment criteria for content, criteria and construct validity as well as reliability, internal consistency and floor and ceiling effects. Agreement, responsiveness and interpretation have not been assessed.

The original *Piper Fatigue Scale* consisted of 40 items [89]; reduced to 22 items in the revised version (PFS-R) [34]. The revised version measured four subscales: behavioural/severity, affective meaning, sensory and cognitive/mood. The scales were validated in 382 breast cancer survivors. Internal consistency was high, over 0.90. The PFS-R has been validated in eight languages. Two psychometric studies were conducted in Italian [30,48]. Other validation studies were performed in Spanish [41], Swedish [27,90], Dutch [47], Portuguese [91], Chinese [35] and Korean [31]. All translated versions of the PFS-R showed good internal consistency. A further reduction in the PFS

items was carried out to create a 12-item scale (PFS-12) [92], with the reliability of the item subscales being between 0.87 and 0.98. The PFS-12 measured four subscales: behavioural, affective, sensory, and cognitive/mood. In people with cancer, the PFS-R met the quality assessment criteria for content, construct, and criterion validity along with reliability and internal consistency. Further work is needed on agreement, responsiveness, floor and ceiling effects and interpretation.

The *Perform Questionnaire* (PQ) [62] consists of 12 items and was originally developed to measure fatigue among Spanish-speaking cancer patients. The scale assesses three dimensions: physical limitations, activities of daily living, and beliefs and attitudes. The scale was validated with a 238 mixed cancer patient population receiving adjuvant treatment, curative treatment, and palliative care. The internal consistency ranged from 0.78 to 0.92. Another psychometric study conducted by Baró et al.[65] found an overall internal consistency of 0.94 and test-retest reliability of 0.83. The PQ had good validity and reliability but was only validated in Spanish. In people with cancer, the PQ meets the quality assessment criteria for content, and construct validity along with reliability, internal consistency, interpretation and floor and ceiling effects. Further work is needed on criterion validity, agreement and responsiveness.

The *Lee Fatigue Scales (LFS)* is an 18-item scale, which was originally developed to measure fatigue in patients with sleep disorders and is also known as the Visual Analogue Scale for Fatigue, (VASF) [93]. The LFS has two subscales: fatigue (13 items) and energy (5 Items). The psychometric properties in cancer patients were assessed by Meek et al. [22]. The scale demonstrated good reliability but low stability because of sensitivity to morning and evening changes [22]. Lerdal et al. [32] evaluated the psychometric properties of the 13 fatigue item subscale of the LFS in 587 mixed cancer patients. Pearson's correlation coefficients of the LFS were deemed acceptable (*test-retest r* =0.88). In people with cancer, the LFS 13-items met the quality assessment criteria for content and construct validity along with internal consistency and responsiveness. Further work is needed on criterion validity, agreement, reliability, floor and ceiling effects and interpretation.

The *Multidimensional Assessment of Fatigue (MAF)* consists of 16 items scored on a scale ranging from 0 to 10 and originally validated in rheumatoid arthritis patients [94]. The MAF has four dimensions of fatigue; severity, distress, and degree of interference in activity of daily living, and timing. Winstead-Fry [24], tested the MAF in a mixed cancer patient population and found adequate internal consistency. Additional psychometric testing was carried out in a cancer population by Meek et al. [22] who reported the overall coefficient alpha to be 0.88. Despite this, the MAF failed to show adequate construct validity in terms of a four factor structure [22]. Several studies did not recommend using MAF unless further validation has been performed in the cancer population [15,17]. In people with cancer, the MAF met the quality assessment criteria for content validity as well as internal consistency. Further testing of criterion and construct validity, reliability, agreement, responsiveness, floor and ceiling effects and interpretation is required.

The *Cancer Fatigue Scale (CFS)* is a 15-item, 5-point Likert scale composed of three domains: physical, affective and cognitive [58]. It was validated in Japanese cancer patients. The reliability coefficients ranged from between 0.84 and 0.88. The construct validity showed a good score for the instrument (0.32 - 0.67). Okuyama et al. [95] tested the CFS in breast cancer patients and found Cronbach's alpha coefficients ranged from 0.76 to 0.89. Validation was completed for the Japanese version only. The CFS was translated into English but not tested psychometrically. Other translations include Chinese [25], Dutch [96], Turkish [52] and Greek [49] with good reliability (0.74 to 0.91). Based on the review findings, the CFS met the quality assessment criteria for content, construct, and criterion validity as well as internal consistency. Further work is needed on agreement, interpretation, floor and ceiling effects and responsiveness.

The *Hirai Cancer Fatigue Scale (HCFS)* is a 15-item, 5-point Likert scale, with three subscales; physical, mental, and cognitive fatigue [50]. The psychometric properties were assessed in a mixed cancer population of 281 patients undergoing treatment. The overall Cronbach's alpha coefficient was 0.94, supporting internal consistency and a test-retest reliability coefficient of 0.82. The HCFS had high reliability and high validity based on the Japanese cancer population, but further

validation is needed for the English version. In people with cancer, the HCFS met the quality assessment criteria for content, criterion, and, construct validity as well as internal consistency and reliability in a Japanese population. Further work is needed on agreement, responsiveness floor and ceiling effects and interpretation.

The *Cancer-Related Fatigue Distress Scale (CRFDS)* is a 20-item scale that was originally investigated in a heterogenous cancer population [59]. The scale used an 11-point numerical rating scale to assess five domains; physical, social, psychological, cognitive, and spiritual fatigue. The scale has very good validity and reliability. The internal consistency reliability was 0.98. In people with cancer, the CRFDS met the quality assessment criteria for content and construct validity as well as internal consistency. The criterion validity, reliability, responsiveness, floor and ceiling effects and interpretation were not reported.

The *Swedish Occupational Fatigue Inventory (SOFI)* is a 25-item scale that was originally validated in work-related fatigue studies [36]. The scale measures five fatigue domains; lack of energy, physical exertion, physical discomfort, lack of motivation, and sleepiness. The SOFI was validated in a mixed Swedish cancer population of 81 patients receiving radiotherapy. The SOFI met the quality assessment criteria for content and criterion as well as internal consistency, interpretation, and floor and ceiling effects. Further work is needed on criterion and construct validity, reliability, agreement, responsiveness, floor and ceiling effects and interpretation. Further psychometric analyses are required with a larger sample size.

The *Wu Cancer Fatigue Scale (WCFS)* has two versions. The original consists of 16 items with a 5-point Likert scale designed to assess physical, emotional, and cognitive fatigue [42]. It was tested in women with breast cancer undergoing chemotherapy. The scale shows adequate reliability and criterion-related validity. The three-factor model was not supported by exploratory factor analysis. The items in the revised WCFS-9 were reduced to 9 items [51]. In people with cancer, the WCFS-9 meets the quality assessment criteria for content, criterion, and construct validity along with

internal consistency. Further work is needed on agreement, reliability, responsiveness and floor and ceiling effects and interpretation.

The Fatigue Functional Impact Scale (FFIS) was constructed to assess fatigue and functional impairment in an 8-item, 10-point Likert scale [97]. The psychometric properties were assessed in 1355 mixed cancer patients receiving chemotherapy. The FFIS showed strong internal consistency with coefficient alpha scores of 0.90. In people with cancer, the FFIS met the quality assessment criteria for content and construct validity along with internal consistency. Criterion validity, agreement, reliability, floor and ceiling effects, interpretation and responsiveness were not assessed.

The General Fatigue Scale (GFS) is a 7-item scale that assesses overall fatigue intensity, distress level and disruptions of daily activity, and was designed to use for randomised controlled trials to measure fatigue at specific time-points [98]. The scale was validated and translated into Chinese [98]; the Cronbach's alpha reliability coefficient was 0.94. In people with cancer, the GFS met the quality assessment criteria for content validity, construct validity, internal consistency and reliability. Criterion validity, agreement, floor and ceiling effects, responsiveness and interpretation were not reported.

Discussion

Assessing the impact of fatigue on people with cancer is imperative for understanding this distressing symptom and necessary for determining the impact of interventions on CRF. This review is the first to perform a quality assessment of CRF scales employing Terwee's criteria of content validity, internal consistency, criterion validity, construct validity, reproducibility, responsiveness, floor and ceiling effects, and interpretability [19]. Twenty-five scales assessed fatigue in adult cancer patients, considerably more than earlier reviews [15,17,18,99]. The quality assessment of CRF indicated that content, criterion, and construct validity along with internal consistency were the most frequently met criteria, demonstrating that the vast majority of scales undergo at least some psychometric testing of validity and internal consistency reliability. On the other hand, reproducibility, in the form of agreement and intraclass correlation reliability, responsiveness, floor

and ceiling effects, and interpretability are generally not assessed and/or reported as part of the psychometric testing. No study explored all of the Terwee et al. [19] quality assessment criteria in evaluating the psychometric properties of CRF scales.

The use of Terwee et al.'s [19] guidelines for assessing the psychometric properties of CRF scales allows users to distinguish between and make a judgment about the most appropriate choice of CRF scale. While each individual quality assessment criterion is important, the Terwee assessment does not result in an overall psychometric rating of an scale; thus, avoiding the assumption that all of the quality assessment criteria are equal. Terwee et al. [19] suggested that the most important criteria of the nine measurement properties was content validity, as absence of content validity can impact all other measurement properties [100]. All of the scales in this review met the criterion for content validity; however, this indicator on its own, may not be helpful to researchers in selecting a CRF instrument.

Although other reviews of CRF scales have been conducted [15–18], this current psychometric review of CRF scales adds to the literature. This review used different search terms and inclusion criteria and the search was conducted in additional databases compared to the previous reviews [15–18]. As a result, this review included more studies by using different Medical Subject Headings (MeSH) terms and databases. This review evaluated scales using the Terwee et al.[19] checklist for critical evaluation of psychometric properties for each of the studies that evaluated CRF scales. Hence, the current review adds new evidence by presenting each scale for CRF using well-defined criteria of psychometric properties. The most comprehensively validated scales were the BFI, FACT-F, MFI-20 and PFS-R. These received positive ratings in content validity, internal consistency, criterion validity, construct validity and reliability. In addition, these scales have been translated and psychometrically tested in different languages; adding to their value for use in people with cancer.

There are several other factors that need to be taken into consideration by researchers and clinicians when choosing a CRF scale. There is a need to clearly understand the phenomenon of CRF. Unfortunately, the lack of a consensus definition has led to the development of multiple scales

assessing various dimensions or domains of CRF phenomena [9]. It is imperative that the conceptual definition of fatigue is logically consistent with operationalization of the concept. The CRF scales assessed within this review have different foci (e.g., some addressed fatigue severity while others assessed impact on function). The focus of the CRF instrument should be consistent with the research question. In addition, the heterogeneity of the type, the stage of cancer, treatment, and type of management may entail different fatigue experiences, in terms of precedence and severity; thus, selection of a CRF scale should consider these factors. For example, the population in which the scale was validated previously should be taken into consideration, as cultural contexts and beliefs may impact on suitability or applicability of scale items.

There are few limitations to this review. Although this review included 71 studies using different Medical Subject Headings (MeSH) terms and databases, it is possible that some psychometrics studies were not included. This review was restricted to studies published in English. Other psychometric studies evaluating CRF scales published in a language other than English were not included in this review.

Conclusion

This review identified seven scales that produce an overall fatigue score and eighteen scales that produce fatigue subscale score with or without an overall fatigue scale score. These scales were drawn from 77 studies assessing fatigue in people with cancer. This paper is the first to conduct a quality assessment of scales used to measure CRF in people with cancer. Four scales meeting the most quality assessment criteria, within a cancer population, two unidimensional (BFI and FACT-F) and two multidimensional (MFI-20 and PFS- R). Consideration should be given when choosing an appropriate scale for research or clinical propose, as each scale measures different dimensions or aspects of CRF. The least likely criteria to be assessed included test-retest reliability, agreement, responsiveness, interpretation, and floor and ceiling effects. Given the importance of linking conceptional and operationalization of fatigue in people with cancer, recommendations to move

forward with a universally accepted definition of fatigue would further help to advance healthcare science and clinical practice.

Table 1: The assessment of measurement properties of CRF scale (N=77):

	Scale					Reproducibility				
		Content Validity	Internal Consistency	Criterion Validity	Construct Validity	Agreement	Reliability	Responsiveness	Floor and Ceiling Effects	Interpretation
1	Brief Fatigue Inventory (BFI) Mendoza et al., [53]	+	+	?	+	0	0	0	0	0
2	BFI-Italian, Catania et al., [43]	+	+	+	+	0	0	0	0	0
3	BFI-Greek, Meztekd et al., [33]	+	+	+	?	0	+	0	0	0
4	BFI-German Radbruch et al. [44]	+	+	+	+	0	+	0	0	0
5	BFI-Taiwanese, Lin et al., [64]	+	+	0	+	0	+	0	0	?
6	BFI-Chinese, Wang et al. [66]	+	+	0	+	0	0	0	0	0
7	BFI-Japanese, Okuyama [45]	+	+	+	+	0	0	0	0	0
8	BFI-Korean, Yun et al., [37]	+	+	?	?	0	0	0	0	0
9	BFI-Indonesian, Paramita et al[67]	+	+	0	+	0	0	0	0	0
10	BFI-Filipino, Mendoza et al., [39]	+	0	0	+	0	0	0	0	0
11	MBFI, Aynehchi et al., [68]	+	+	0	+	0	+	0	0	0
12	MBFI, Eden & Kunkel, [21]	+	+	+	0	0	+	0	0	0
13	FIFS, Davis et al., [38]	?	0	+	-	0	0	0	0	0
14	FACT-F, Yellen, et al, [46]	+	+	+	0	0	+	0	0	0
15	FACT-F, Spanish, Dapueto, et al, [61]	+	+	0	+	0	+	?	0	0
16	FACT-F, French and Dutch, Van Belle et al., [70]	+	+	0	+	0	0	0	0	0
17	FACT-F, Portuguese, Ishikawa et al., [72]	+	+	0	+	0	+	0	0	0
18	FACT-F, Portuguese, Ishikawa et al., [26]	0	0	0	0	+	+	0	0	0
19	FACT-F, Japanese, Yoshimura et al., [40]	+	0	0	+	0	+	0	0	0
20	FACT-F, Persian, Meysami, et al., [71]	+	+	0	+	0	+	0	0	0
21	FACT-F, Eden & Kunkel [21]	+	+	+	0	0	+	0	0	0
22	Fatigue Assessment Scale (FAS), De Vries et al [75]	+	+	0	+	0	+	0	0	0
23	Fatigue Severity Scale FSS, Winstead-Fry P.,[24]	+	+	0	+	0	0	0	0	0
24	FSS, Stone et al, [54]	?	+	?	+	0	+	0	0	0
25	FSS, Stone et al, [28]	?	?	0	0	0	+	0	0	0
26	Fatigue items bank (FIB) Lai et al, [63]	+	+	0	+	0	0	0	+	0
	Multidimensional instrument									
27	Multidimensional Fatigue Inventory (MFI-20) MFI-20-Dutch, Smets et al., [77]	+	+	0	+	0	0	0	0	0
28	MFI-20 English, Smets et al. [78]	+	+	0	+	0	0	0	0	0
29	MFI-20 Brazilian, Portuguese Baptista et al. [79]	+	+	0	+	0	0	0	0	0
30	MFI-20 Polish, Buss et al. [55]	+	+	?	+	0	0	0	0	0
31	MFI-20 Swedish, Lundh et al. [81]	?	+	0	+	0	0	0	0	0

32	MFI-20 French, Fillion et al., [56]	+	+	?	+	0	0	0	0	0
33	MFI-20 Hindi, Chandel et al. [80]	+	+	0	+	0	0	0	0	0
34	MFI-20 Chinese , Tian & Hong [57]	+	+	?	+	0	0	0	0	0
35	Fatigue Symptom Inventory-Short Form Stein et al., [82]	+	+	0	+	0	+	0	0	0
36	MFSI-SF Stein et al., [83]	+	+	0	+	0	0	0	0	0
37	MFSI-SF-C Pien et al., [84]	+	+	0	+	0	+	0	0	0
38	MFSI-SF-C Chan et al., [60]	+	+	0	+	0	+	?	0	0
39	Schwartz Cancer Fatigue Scale SCFS Schwartz,[85]	+	+	0	+	0	0	0	0	0
40	SCFS-R, Schwartz & Meek, [86]	+	+	0	+	0	0	0	0	0
41	SCFS-R Schwartz et al., [29]	+	?	0	0	0	?	+	0	0
42	SCFS-R Chinese, Shun et al. [25]	+	+	0	+	0	0	0	0	0
43	SCFS-R Chinese Shun et al. [23]	+	+	0	+	0	?	0	+	0
44	Fatigue Symptom Inventory FSI, Hann et al [87]	+	+	0	+	0	0	0	0	0
45	FSI Hann et al [88]	+	+	0	+	0	0	0	0	0
46	FSI- Chinese, Shun, et al. [25]	+	+	0	+	0	0	0	0	0
47	FSI- Chinese, Shun, et al. [23]	+	+	0	+	0	?	0	+	0
48	Piper Fatigue Scale-Revised (PFS-R) Piper et al. [34]	+	+	0	?	0	?	0	0	0
49	PFS-R Korean, Lee [31]	+	+	0	?	0	+	0	0	0
50	PFS-R Spanish, Cantarero-Villanueva et al., [41]	+	0	0	+	0	0	0	0	0
51	PFS-R Swedish, Jakobsson et al, [27]	+	+	+	+	0	0	0	0	0
52	PFS-R Swedish, Lundgren-Nilsson, et al., [90]	?	?	0	+	0	0	0	0	0
53	PFS-R Dutch, Dagnelie et al. [47]	+	+	+	+	0	0	0	0	0
54	PFS-R Brazilian, Mota et al. [91]	+	+	0	+	0	0	0	0	0
55	PFS-R Italian Giacalone et al. [48]	+	+	+	+	0	0	0	0	0
56	PFS-R Italian, Annunziata et al. [30]	+	+	0	?	0	0	0	0	0
57	PFS-R Chinese So et al., [35]	?	+	0	?	0	0	0	0	0
58	PFS-12 Reeve et al. [92]	+	+	0	+	0	0	0	0	0
59	Perform Questionnaire Baró et al., [62]	+	+	0	+	0	0	0	+	0
60	PQ, Baró et al., [65]	+	+	0	+	0	+	0	0	+
61	Lee Fatigue Scale (LFS) Meek et al., [22]	+	+	0	+	0	0	?	0	0
62	Lee Fatigue Scale (LFS) Lerdal et al., [32] only 13-items of fatigue.	+	+	0	?	0	+	0	?	?
63	Multidimensional Assessment of Fatigue (MAF) Meek et al. [22]	+	+	0	+	0	0	?	0	0
64	MAF Winstead-Fry [24]	+	+	0	+	0	0	0	0	0
65	Cancer Fatigue Scale (CFS) Okuyama et al., [58]	+	+	?	+	0	+	0	0	0
66	CFS -J Okuyama et al., [95]	+	+	0	+	0	0	0	0	0

67	CFS- Chinese, Shun et al., [25]	+	+	0	+	0	0	0	0	0
68	CFS- Dutch, Kröz et al., [96]	+	+	0	+	0	0	0	0	0
69	CFS- Turkish, ŞAHİN, et al., [52]	+	+	+	+	0	+	0	0	0
70	CFS- Greek Charalambous, et al., [49]	+	+	+	+	0	+	0	0	0
71	Hirai Cancer Fatigue Scale Hirai et al., [50]	+	+	+	+	0	+	0	0	0
72	Cancer-Related Fatigue Distress Scale (CRFDS) Holley [59]	+	+	0	+	+	0	0	0	0
73	Swedish Occupational Fatigue Inventory Åhsberg & Fürst [36]	+	+	0	?	0	0	0	0	0
74	16-item scale (WCFS), Wu & McSweeney, [42]	+	0	+	+	0	0	0	0	0
75	Wu Cancer Fatigue Scale (WCFS-9) Wu et al., [51]	+	+	+	+	0	0	0	0	0
76	Fatigue Functional Impact Scale (FFIS) Cella et al., [97]	+	+	0	+	0	0	0	0	0
77	General Fatigue Scale (GFS), Chou et al., [98]	+	+	0	+	0	+	0	0	0

Table S1: Quality criteria for measurement properties of scales

	Property	Definition		Quality Criteria
1	Content validity	The amount to which the domain of Interest is comprehensively sampled by the items in the questionnaire	+	A clear description is provided of the measurement aim, the target population, the concepts that are being measured, and the item selection AND target population and (investigators OR experts) were involved in item selection;
			?	A clear description of above-mentioned aspects is missing, OR only target Population involved OR doubtful design or method;
			-	No target population involvement;
			0	No information found on target population involvement.
2	Internal Consistency	The amount to which items in a (sub) scale Are intercorrelated, so measuring the same construct	+	Factor analyses performed on adequate sample size (7 * # items and> 100) AND Cronbach's alpha (s) calculated per dimension AND Cronbach's alpha (s) Between 0.70 and 0.95;
			?	No factor analysis OR doubtful design or method;
			-	Cronbach's alpha (s)! 0.70 or O0.95, despite adequate design and method;
			0	No information found on internal consistency.
3	Criterion validity	The extent to which scores on a Particular questionnaire refer to a gold Standard	+	Convincing arguments that gold standard is " gold " AND correlation with gold standard> 0.70;
			?	No convincing arguments that gold standard is " gold " OR doubtful design or Method;
			-	Correlation with gold standard! 0.70, continuous adequate design and method;
			0	No information found on criterion validity.
4	Construct validity	The amount to which scores on a Particular questionnaire refer to other Measures in a manner that is consistent with theoretically derived hypotheses Relating the concepts that are being measured	+	Specific hypotheses were formed and at least 75% of the results are in accordance with these hypotheses;
			?	Doubtful design or method (eg, no hypotheses
			-	Less than 75% of hypotheses were confirmed, despite adequate design and Methods;
			0	No information found on construct validation.
5	Reproducibility			
	5.1. Agreement	The amount to which the scores on repeated measures are close to each other (absolute measurement error)	+	MIC! SDC OR MIC outside the LOA OR convicting arguments that agreement is acceptable;
			?	Doubtful design or method OR (MIC not defined AND no convincing arguments that agreement is acceptable
			-	MIC> SDC OR MIC equals or inside LOA, despite adequate design and method;
			0	No information found on agreement.
	5.2. Reliability	The amount to which patients can be	+	ICC or weighted Kappa> 0.70;
			?	Doubtful design or method (eg, time interval not mentioned);

		Distinguished from each other, despite Measurement errors (Relative measurement error)	-	ICC or weighed Kappa! 0.70, despite adequate design and method;
			0	No information found on reliability.
6	Responsiveness	The ability of a questionnaire to detect Clinically important changes over time	+	SDC or SDC! MIC OR MIC outside the LOA OR RRO1.96 OR AUC> 0.70;
			?	Doubtful design or method;
			-	SDC or SDC> MIC OR MIC equals or inside LOA OR RR <1.96 OR AUC! 0.70, despite adequate design and methods
			0	No information found on responsiveness.
7	Floor and ceiling Effects	The number of responders who achieved the lowest or highest possible score	+	<15% of the respondents achieved the highest or lowest possible scores;
			?	Doubtful design or method;
			-	>15% of the respondents achieved the highest or lowest possible scores, strict adequate design and methods;
			0	No information found on interpretation.
8	Interpretability	The degree to which one can assign Qualitative meaning to quantitative scores	+	Mean and SD scores presented at least four relevant subgroups of patients and MIC defined;
			?	Doubtful design or method OR less than four subgroups OR no MIC defined;
			0	No information found on interpretation.

* This table adapted from Terwee et al.[19] page 39

Table S2: Characteristics of the Studies

	Scale with references	Design	Fatigue definition	Sample	Type of cancer	***Time of intervention***	Language	Internal consistency Cronbach's Coefficient Alpha	Test & Retest Correlation coefficient
	Unidimensional Scales								
1	Brief Fatigue Inventory (BFI) Mendoza et al., [53] USA	Cross-sectional	Not given	305	Mixed Cancer Patient	Not specify	English	α 0.96	
2	BFI-Italian, Catania et al., [43] Italy	Cross-sectional	Not given	341	Mixed Cancer Patient	Mixed	Italian	α 0.94	
3	BFI-Greek, Meztekd et al., [33] Greek	Longitudinal	Not given	102	Mixed Cancer Patient	Mixed	Greek	α 0.95	
4	BFI-German Radbruch et al. [44] Germany	Longitudinal	Def (2)	117	Mixed Cancer Patient	Not specify	German	α 0.91	
5	BFI-Taiwanese, Lin et al., [64] Taiwan	Longitudinal	Def (1)	439	Mixed cancer Patients	Not specify	Chinese (Taiwanese)	α 0.96	
6	BFI-Chinese, Wang et al. [66] China	Cross-sectional	Not given	249	Mixed cancer Patients	Mixed	Chinese	α 0.86 to 0.91	
7	BFI-Japanese, Okuyama [45] Japan	Cross-sectional	Not given	252	Mixed cancer Patients	Mixed	Japanese	α 0.96	
8	BFI-Korean, Yun et al., [37] Korea	Cross-sectional	Not given	178	Mixed cancer Patients	Not specify	Korean	α 0.95	
9	BFI-Indonesian, Paramita et al., [67] Indonesia	Cross-sectional	Not given	121	Mixed cancer Patients	Not specify	Indonesian	α 0.95	
10	BFI-Filipino, Mendoza et al., [39] Philippines	Cross-sectional	Not given	206	Mixed cancer Patients	Mixed	Filipino	α 0.95	
11	MBFI, Aynehchi et al., [68] USA	Longitudinal	Not given	52	Head and Neck cancer	Mixed	English	α 0.938	Test & Retest r =0.814
12	MBFI, Eden & Kunkel, [21] USA	Longitudinal	Def 18	65	Head and neck skin and thyroid cancer	Mixed	English	α 0.869	Test & Retest r =0.865
13	Fatigue Functional Impact Scale (FFIS), Davis et al., [38] USA	Longitudinal	Def (3)	65	Mixed advanced cancer Patients	Not specify	English		

14	Functional Assessment of Chronic Therapy-Fatigue (FACT- F) Yellen, et al. [46] USA	Longitudinal	Def 4	49	Mixed Cancer Patient	Mixed	English	α 0.90 C. α 0.93 to 0.95	Test & Retest r =0.87
15	FACT- F, French and Dutch Van Belle et al., [70] Belgium	Cross-sectional	Def 5	834	Mixed Cancer Patient	Mixed	French and Dutch	α 0.94	
16	FACT-F, Spanish Dapueto, et al, [61] Uruguay	Longitudinal	Def 4	79	Mixed cancer patients	Mixed	Spanish	α 0.88	
17	FACT-F, Portuguese Ishikawa et al., [72] Brazil	Longitudinal	Not given	270	Mixed cancer patients	Mixed	Portuguese	α 0.92	
18	FACT-F, Portuguese Ishikawa et al., [26] Brazil	Longitudinal	Not given	85	Mixed cancer patients	Mixed	Portuguese	α 0.79	Test & Retest r = 0.85
19	FACT- F, Japanese Yoshimura et al., [40] Japan	Cross-sectional	Not given	180	Lung cancer	Not specify	Japanese	α 0.93	Test-retest r =0.43-0.70
20	FACT-F, Persian Meysami, et al., [71] Iran	Longitudinal	Not given	208	Breast cancer	Completed treatment	Persian	α 0.91	Test-retest r =0.91
21	FACT-F, Eden & Kunkel, [21] USA	Longitudinal	Def 18	65	Head and neck skin and thyroid cancer	Mixed	English	α 0.911	Test & Retest r =0.951
22	Fatigue Assessment Scale (FAS) De Vries et al [75] Netherland	Longitudinal	Not given	204	Breast cancer	Not specify	Dutch	α 0.88 to 0.90	Test & Retest r =0.87 and r =0.88
23	Fatigue Severity Scale (FSS) Winstead-Fry P., [24] USA	Cross-sectional	Def 17	131	Mixed cancer Patients	Not specify	English	α =0.95	
24	FSS, Stone et al, [54] UK	Longitudinal	Def 6	95	Mixed advanced cancer Patients	Not specify	English	α =0.94	Test-retest reliability Calculated by measurement error was 4.7
25	FSS, Stone et al, [28] UK	Longitudinal	Def 7	227	Mixed cancer Patients	Not specify	English	α =0.96	Test-retest reliability Calculated by measurement error was 4.7 unites (satisfactory)

26	Fatigue Items Bank (FIB) Lai et al, [63] USA	Cross-sectional	Def 11	301	Mixed cancer patients	Not specify	English	α =0.96	
	Multidimensional Scales								
27	Multidimensional Fatigue Inventory (MFI-20) Dutch, Smets et al., [77] Netherland	Cross-sectional	Not given	111	Mixed cancer Patients	Receiving Radiotherapy	Dutch	α 0.84	
28	MFI-20 English, Smets et al. [78] Netherland and UK	Cross-sectional	Not given	98 Dutch 116 Scottish	Mixed cancer Patients	Receiving Radiotherapy	English, Dutch	Overall 0.79-0.93	F.A. (0.98 Dutch), 0.97 Scottish) α 0.83
29	MFI-20 Brazilian, Portuguese Baptista et al. [79] Brazil	Cross-sectional	Not given	200	Hodgkin's lymphoma	Completed treatment	Brazilian Portuguese	α 0.84 α 0.59 to 0.81.	
30	MFI-20 Polish, Buss et al. [55] Poland	Cross-sectional	Def 1	340	Mixed cancer patients	Not specify	Polish	α 0.90 α 0.57 to 0.81	
31	MFI-20 Swedish, Lundh et al. [81] Sweden	Cross-sectional	Not given	584	Mixed cancer Patients	Mixed	Swedish	α 0.67 to 0.94	
32	MFI-20 French, Fillion et al., [56] French	Cross-sectional	Not given	604	277 Breast 327prostate	Mixed	French	Over all α 0.90 α 0.68 to 0.89	
33	MFI-20 Hindi, Chandel et al. [80] India	Cross-sectional	Not given	200	Head and neck, Breast, cervical	Mixed	Hindi	Over all α 0.8 α 0.71 to 0.82	
34	MFI-20 Chinese , Tian & Hong [57] China	Cross-sectional	Not given	385	Mixed cancer Patients	undergoing chemotherapy	Chinese	α 0.87 α .71 to .82	
35	Multidimensional Fatigue Symptom Inventory-Short Form (MFSI-SF), Stein et al., [82] USA	Longitudinal	Def 9	224	Breast cancer	Mixed	English	α 0.90 to 0.96	r=0.21 - 0.82
36	MFSI-SF, Stein et al., [83] USA	Cross-sectional	Not given	304	Mixed cancer Patients	undergoing chemotherapy	English	α 0.85 to 0.960	10
37	MFSI-SF Chinese Pien et al., [84] China	Cross-sectional	Def 8	107	Mixed cancer Patients	Not specify	Chinese	Over all α 0.93 α 0.83 to 0.92	
38	MFSI-SF Chinese Chan et al., [60] Singapore	Longitudinal	Not given	246	Breast cancer and lymphoma patients	undergoing Chemotherapy	Chinese Singapore	α = 0.749 to 0.944	r=0.005 - 0.185

									poorly correlated
39	Schwartz Cancer Fatigue Scale (SCFS) Schwartz,[85] USA	Cross-sectional	Def 11	166	Mixed cancer Patients	Mixed	English	Over all α 0.96 α 0.82 to 0.93	
40	SCFS-R, Schwartz & Meek, [86] USA	Cross-sectional	Not given	303	Mixed cancer Patients	Mixed	English	Over all α 0.90 α 0.81 to 0.88	
41	SCFS-R Schwartz et al., [29] USA	Longitudinal	Not given	226	Mixed cancer Patients	Before chemo and after chemo	English	Over all C. α 0.85	
42	SCFS-R Chinese, Shun et al. [25] China	Cross-sectional	Def 10	243	Mixed cancer Patients	Mixed	Chinese	Over all α 0.88 α 0.81 to 0.90	
43	SCFS-R Chinese Shun et al. [23] China	Longitudinal	Not given	148	Mixed cancer Patients	Mixed	Chinese	Over all α =0.89	
44	Fatigue Symptom Inventory (FSI), Hann et al [87] USA	Cross-sectional	Not given	230	Breast cancer	Mixed	English	Over all α = 0.90	
45	FSI Hann et al [88] USA	Cross-sectional	Not given	270	Mixed cancer patients	Not specify	English	Over all α = 0.94	
46	FSI- Chinese, Shun, et al. [25] China	Cross-sectional	Def 10	243	Mixed cancer Patients	Mixed	Chinese	Over all α > 0.90	
47	FSI- Chinese, Shun, et al. [23] China	Longitudinal	Not given	148	Mixed cancer Patients	Mixed	Chinese	Over all α =0.70	
48	Piper Fatigue Scale-Revised (PFS-R) Piper et al. [34] USA	Cross-sectional	Not given	382	Breast cancer patients	Completed treatment	English	α 0.92 to 0.96	
49	PFS-R Korean, Lee [31] Korea	Cross-sectional	Not given	122	Breast cancer patients	Mixed	Korean	α 0.84 to 0.93	
50	PFS-R Spanish, Cantarero-Villanueva et al., [41] Spain	Cross-sectional	Not given	111	Breast cancer patients	Completed treatment	Spanish	Over all α 0.89	(r > 0.86)
51	PFS-R Swedish, Jakobsson et al, [27] Sweden	Cross-sectional	Not given	196	Mixed cancer Patients	undergoing Radiotherapy	Swedish	Over all α 0.98 α 0.93 to 0.97	
52	PFS-R Swedish, Lundgren-Nilsson, et al., [90] Sweden	Cross-sectional	Not given	196	Mixed cancer Patients	undergoing Radiotherapy	Swedish		Construct validity reported by Rasch analyses

53	PFS-R Dutch, Dagnelie et al. [47] Netherlands	Cross-sectional	Not given	64	Lung and Breast cancer	Before Radiotherapy	Dutch	Over all α >0.90	
54	PFS-R Brazilian, Mota et al. [91] Brazil	Cross-sectional	Not given	584	Mixed cancer Patients	Mixed	Portuguese	Over all α 0.841 to 0.943	
55	PFS-R Italian Giacalone et al. [48] Italy	Cross-sectional	Def 10	115	Mixed cancer patient	Not specify	Italian	Over all α =95 α 0.80 to 0.94	r=0.77
56	PFS-R Italian, Annunziata et al. [30] Italy	Cross-sectional	Def 10	100	Mixed cancer Patients	Not specify	Italian	Over all α =95 α 0.88 to 0.91	
57	PFS-R Chinese So et al., [35] China	Cross-sectional	Def 19	157	Mixed cancer Patients	Mixed	Chinese	Over all α 0.89 to 0.93	
58	PFS-12 Reeve et al. [92] - USA	Longitudinal	Def 12	799	Breast cancer survivors	Completed treatment	English	Over all α >0.80 α 0.87 to 0.89	
59	Perform Questionnaire (PQ) Baró et al., [62] Spain	Cross-sectional	Def 10	238	Mixed cancer patients	Mixed	Spanish	α 0.73 to 0.92	
60	PQ, Baró et al., [65] Spain	Longitudinal	Def 13	437	Mixed cancer patients	Mixed	Spanish	Over all α >0.94 α 0.80 to 0.90	r=0.83
61	Lee Fatigue Scale (LFS) Meek et al., [22] USA	Cross-sectional	Not given	212	Mixed cancer patients	Mixed	English	Over all α The variance did not support instrument constrict validity	
62	Lee Fatigue Scale (LFS) single fatigue only used Lerdal et al., [32]-USA	Longitudinal	Not given	587	Mixed cancer Patients	Mixed	English	Over all α =0.89	Test & Retest r=0.88
63	Multidimensional Assessment of Fatigue (MAF), Meek et al. [22] USA	Cross-sectional	Not given	212	Mixed cancer patients	Mixed	English	Over all α =0.88	
64	MAF, Winstead-Fry [24]USA	Cross-sectional	Def 17	131	Mixed cancer Patients	Not specify	English	Over all α =0.89	
65	Cancer Fatigue Scale (CFS) Okuyama et al., [58] Japan	Longitudinal	Def 14	307	Mixed cancer Patients	Not specify	Japanese	Over all α = 0.88 0.84 to 0.88	r=0.32-0.67

66	CFS -J Okuyama et al., [95] Japan	Cross-sectional	Not given	134	Breast cancer	Completed treatment	Japanese	0.76 to 0.89	
67	CFS- Chinese, Shun et al., [25] China	Cross-sectional	Def 10	243	Mixed cancer Patients	Mixed	Chinese	Over all α =0.83	
68	CFS- Dutch, Kröz et al., [96] Germany	Longitudinal	Def 15	114	57 healthy persons 57 mixed cancer patients	Mixed	German (Dutch)	Over all α =0.94	r= 0.82
69	CFS- Turkish, ŞAHİN, et al., [52] Turkey	Longitudinal	Def 15	80	Breast cancer	Completed treatment	Turkish	Over all α =0.74	ICC 0.95
70	CFS- Greek Charalambous, et al., [49] Greek	Cross-sectional	Def 18	148	Prostate cancer	Completed treatment	Greek	Over all α =0.916	r = 0.79, p <0.001)
71	Hirai Cancer Fatigue Scale (HCFS) Hirai et al., [50] USA	Longitudinal	Not given	281	Mixed cancer Patients	Mixed	Japanese	Over all α =0.977	r = .589-0.913
72	Cancer-Related Fatigue Distress Scale (CRFDS) Holley [59] USA	Cross-sectional	Not given	221	Mixed cancer Patients	Mixed	English	Over all α =0.943	(*r* = 0.65)
73	Swedish Occupational Fatigue Inventory Åhsberg & Fürst [36] Sweden	Cross-sectional	Not given	81	Mixed cancer patients	undergoing radiotherapy	Swedish	α 0.73 to 0.97	
74	16-item scale (WCFS), Wu & McSweeney, [42] - USA	Cross-sectional	Def 3	82	Breast carcinoma	undergoing Chemo	English	Over all α >0.95	
75	Wu Cancer Fatigue Scale (WCFS) R Wu et al., [51] USA	Cross-sectional	Not given	172	Breast cancer	undergoing Chemo	English	Over all α =0.91	
76	Fatigue Functional Impact Scale (FFIS) Cella et al., [97] - USA	Cross-sectional	Not given	401	Mixed cancer patients	undergoing Chemo	English	Over all α =0.90	
77	General Fatigue Scale (GFS), Chou et al., [98] – Taiwan	Longitudinal	Def 17	171	Breast Cancer	undergoing Chemo	Chinese - Taiwanese	Over all α =0.94	

α, *coefficient alpha*

Table S3: Definition of fatigue in the studies:

	Definition
Def :1	Fatigue is a subjective symptom and is generally thought to be related to feelings of weakness, tiredness, and lack of energy. [64]
Def :2	As a multidimensional construct involving physical exhaustion, mental tiredness and a lack of energy [101]
Def :3	(ICD-10), cancer-related fatigue (CRF) is defined as diminished energy, an increasing need for rest, limb heaviness, diminished ability to concentrate decreased interest in engaging in normal activities, sleep disorder, inertia, emotional liability, perceived problems with short-term memory, and postexertional malaise exceeding several hours and so on. [102]
Def 4	It is defined as a subjective sensation of weakness, lack of energy, or tiredness.[61]
Def 5	Being unusual or abnormal, absolutely disproportionate with respect to the amount of exercise or activity he / she has carried out, and not alleviated by resting or sleeping. [103]
Def 6	A subjective sensation of feeling easily tired, weak or lacking in energy. [54]
Def 7	As the subjective sensation of having reduced energy, loss of strength or becoming easily tired.[28]
Def 8	Cancer-related fatigue is defined as a subjective, unusual and continuous feeling that it is cancer, it is associated or treatment- related and affects daily living activities [104]
Def 9	Objectively, fatigue may be defined as a behavioral or physiologic symptom, exhibited by impaired physical, social, and vocational functioning.[82]
Def 10	" A persistent, subjective sense of tiredness related to cancer or cancer treatment that interferes with usual functioning'. [105]
Def 11	(NANDA) definition, which is "an overwhelming, sustained sense of exhaustion and reduced capacity for physical and mental work " [106]
Def 12	The perception of unusual tiredness that varies in pattern or severity and can affect the functional ability of cancer survivors [107]
Def 13	"Distressing persistent subjective sense of physical, emotional, and / or cognitive tiredness "[108]
Def 14	Condition characterized by a subjective feeling of a decrease in energy, and it has both physical and psychological aspects. [109]
Def 15	A persistent feeling of loss of energy and performance, fatigue, increased tiredness, lack of energy or motivation and problems with concentration. [110]
Def 16	"Fatigue is a subjective state of overwhelming and sustained exhaustion and decreased capacity for physical and mental work that is not disclosed by rest [111]
Def 17	As a subjective experience of tiredness, decreased energy, and decreased mental and motor skills associated with cancer therapy. [112]
Def 18	"A disturbing, persistent, subjective sense of physical, emotional, and / or cognitive fatigue or exhaustion related to cancer or cancer treatment that is not proportional to recent activity and interferes with usual functioning." [10]
Def 19	"An abnormal, abnormal, or excessive whole-body tiredness disproportionate to, or unrelated to, activity or exertion." Page 279 [113]

Table S4: Unidimensional scales

	Instrument	Number of Items	Domain	Fatigue Indication	Type of scale	Time to complete	Time period assessed
1	Brief Fatigue Inventory (BFI) Mendoza et al., (1999) [53]	9	Physical functional	1-3 Mild 4-6 Moderate 7-10 severe	11-Numerical (0-10)	5 min	Past 24h
2	Modified Brief Fatigue Inventory (MBFI) Aynehchi et al., (2013) [68]	9	Physical functional		7-Numerical	Not Stated	Past 24h
3	Four-Items Fatigue Scale (FIFS), Davis et al., (2013)[38]	4	Physical functional	1-3 Mild 4-6 Moderate 7-10 severe	10-Numerical	Not Stated	Past 24h
4	Functional Assessment of Chronic Therapy-Fatigue (FACT- F) Yellen, et al. (1997) [46]	13	Physical Functioning	Cut-off 36 had Sensitively	5-point Likert scale	5-10 min	Past 7 days
5	Fatigue Assessment Scale (FAS) De Vries et al (2010) [75]	10	Fatigue	Higher score indicated fatigue	5-point Likert scale	Not Stated	Present
6	Fatigue Severity Scale (FSS) Winstead-Fry P., (1998) [24]	9	Severity	Cut-off 5	7-point Likert scale	Not Stated 2-3mint Properly	Present
7	Fatigue Items Bank (FIB) Lai et al, (2005) [63]	72	Fatigue	Higher score indicated more fatigue	5-point Likert scales	20 min	Past 7 days

Table S5: Multidimensional Scales

	Scale	Number of items	No Domain	Domain	Fatigue Indication	Type of scale	Time to complete	Time period assessed
1	Multidimensional Fatigue Inventory (MFI-20) Smets et al., (1995) [77]	20	5	General, physical, reduced activity, reduced motivation and mental fatigue	4(absence fatigue) 20(maximum fatigue)	5-point Likert scale	5-10 min	Present
2	Multidimensional Fatigue Symptom Inventory-Short Form	30	5	General fatigue, mental, physical, emotional and Vigor	Higher score indicated	5-point Likert scale	5 mints	Past 7 days

	(MFSI-SF) Stein et al. (1998) [82]				more fatigue			
3	Schwartz Cancer Fatigue Scale (SCFS) Schwartz, (1998) [85]	28	4	Physical, emotional, cognitive and temporal	Higher score indicated more fatigue	5-point Likert scale	5 mints	2 to 3 days
4	Schwartz Cancer Fatigue Scale-6 (SCFS-6) Schwartz and Meek (1999)[86]	6	2	Physical and Perceptual	Higher score indicated more fatigue	5-point Likert scale	1 to 2 min	2 to 3 days
5	Fatigue Symptom Inventory (FSI) Hann et al (1998) [87]	13	4	intensity, duration, daily pattern and interference	Cut-off 3 fatigue	11-point Likert only One with 7 points	5 min	Past 7 days, current
6	Piper Fatigue Scale-Revised (PFS-R) Piper et al. (1998) [34]	22	4	behaviour / severity, sensory, mood/ cognitive and affective meaning	0 non 1-3 Mild 4-6 Moderate 7-10 Severe	11-point (0-10) numeric scales	5 min	Now
7	PFS-12 Reeve et al. (2013) [92]	12	4	behavioral, sensory, mood/ cognitive and affective	0 non 1-3 Mild 4-6 Moderate 7-10 Severe	11-point (0-10) numeric scales	<5 min	Now
8	Perform Questionnaire (PQ) Baró et al., (2009) [62]	12	3	Physical Limitations, Activities of Daily Living, and Beliefs and Attitudes.	Higher score indicated worse fatigue	5-point ordinal scale	<9 min	2 weeks
9	Lee Fatigue Scale (LFS) Meek et al., (2000) [22]	18	2	Fatigue and energy	Higher score indicated greater fatigue	11-point (0-10) numeric scales	>2 min	Current
10	Multidimensional Assessment of Fatigue (MAF) Meek et al., (2000) [22]	16	4	Severity, distress, Interference in activity daily level, and timing	1 (no fatigue) 50 (severe fatigue)	0-10	<5 min	Past 7 days
11	Cancer Fatigue Scale (CFS) Okuyama et al., (2000) [58]	15	3	Physical, affective and Cognitive	1 (no fatigue) 60 (severe fatigue)	5-point Likert scale	2-3 min	Current
12	Hirai Cancer Fatigue Scale (HCFS) Hirai et al., (2015) [50]	15	4	Physical, Mental, and Cognitive fatigue	Higher score indicated greater fatigue	5-point Likert scale	Not Given probably 2-5 min	Current
13	Cancer-Related Fatigue Distress	23	5	Physical, Social, Psychological,	Higher score	11-point	Not	Current

	Scale (CRFDS) Holley (2000) [59]			Cognitive and Spiritual	indicated severe fatigue	(0-10) numeric scales	Given probably 3-5 min	
14	Swedish Occupational Fatigue Inventory (SQFI) Åhsberg & Fürst (2001) [36]	25	5	Lack of energy, Physical exertion, Physical discomfort Lack of motivation and Sleepiness	Higher score indicated more fatigue (0-6) > 2 indicted fatigue	7-point Likert scale	Not Given probably 5-8 min	Current
15	16-item scale (WCFS) Wu & McSweeney, (2004) [42]	16	3	Physical Emotional and cognitive	Higher score indicated more fatigue (15-75)	5-point Likert scale	Not Given probably 5 min	Past 1 day
16	Wu Cancer Fatigue Scale (WCFS) R Wu et al., (2006) [51]	9	3	Physical Emotional and cognitive	Higher score indicated more fatigue (9-45)	5-point Likert scale	Not Given probably 2-3 min	Past 1 day
17	Fatigue Functional Impact Scale (FFIS) Cella et al., (2008) [97]	8	2	Fatigue and functional impairment	Higher score indicated more fatigue	10-point numeric scales	2-3 min	Past Month
18	General Fatigue Scale (GFS) Chou et al., (2016) [98]	7	3	Intensity, distress, disruption of daily activities	Higher score indicated more fatigue	10-point numeric scales	3-5 min	Past 7 days

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